THE GROWTH OF CLOVER IN THE PRESENCE OF AMMONIUM SULPHATE

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It has long been held that the treatment of grassland with nitrogenous fertilizers, and especially with ammonium salts, reduces the clover content. This method has been applied also to the treatment of lawns and sports fields with a view to reducing the clover content of the turf. It has been suggested that the effect of the ammonium salts is to encourage the growth of the grass in competition with the clover, and also that the ammonium ions are specifically toxic to the clover plant. Since there is a growing volume of evidence that ammonium ions are, in fact, available to many plants and may be used by them directly, without nitrate-formation, it was thought desirable to examine the effect of the application of ammonium sulphate to clover plants grown in pots, where competition from grasses was not a factor in the consideration of the effect of manurial treatment.

In the first experiment Alsike clover seed was sown in sixteen pots each containing between 1 and 2 kg. of potting soil. The seed was sown in all pots on August 2, 1934. At the same time, the pots were grouped into four sets each of four pots. To the first set was added 1 gm. of ammonium sulphate per pot, to the second 0·5 gm. of ammonium sulphate, to the third 0·25 gm. of ammonium sulphate and the fourth was kept as a control. During the next few days the seeds germinated and the seedlings were thinned out as soon as the first foliage leaf appeared. Five plants were left in each pot, but further seeds germinated later. On September 20 another dressing of ammonium sulphate was given, each pot receiving the same dressing on this as on the previous occasion. This and all subsequent dressings were given in solution to ensure that an unduly high concentration of the sulphate did not become available to a single plant. The treatments were repeated in 1934 on these dates, viz. October 4, 18, November 1, 15, 29, December 13. In October the plants were taken into a cold glasshouse to prevent the washing of the soil in the heavy rains and to prevent damage to the foliage by wind. From the beginning of the experiment the pots had been placed in

earthenware saucers to reduce to a minimum the loss of salts by leaching. The treatments were continued on January 17, 31, February 7, 21, March 14, 28, April 11, 25, May 9, 16, 30, June 13, July 4, 18, August 1, 15, 1935. Thus by the end of the experiment the "1 gm." series had received altogether 24 gm. of ammonium sulphate per pot. After May 9, the pots were again placed outside and the plants came into flower about the beginning of June. At no time in the experiment was there any evidence that the ammonium sulphate had any but a slight beneficial effect on the clover plants, as the plants receiving sulphate, especially at the highest level, were even darker green than the controls. All the plants grew very well indeed, and flowered profusely: in the early stages of the experiment the ammonium sulphate plants were clearly larger and better grown than the controls, but this difference disappeared later.

On December 6, 1934, after the experiment had been running for five months, and a week after the seventh application of sulphate, four of the pots, one from each treatment, were taken for analysis. A few root nodules were observed in all the pots. The plants, both tops and roots, and the soils were weighed and analysed (Tables I and II). Ammonia and nitrate nitrogen were determined in the fresh soils by Carsten Olsen's method, the sum of these two being shown in Table I as "mineral nitrogen". The "extra mineral nitrogen", obtained by subtracting that in the control pot from the mineral nitrogen in the treated pots, shows how much of the nitrogen added as ammonium sulphate was still present in the soils. Considerable amounts of nitrate and also, in the "1 gm." pot, a large amount of ammonia were found in the treated soils. Since over half of this ammonia was water-soluble, ammonium ions were doubtless present.

On May 29, 1935, the plants from two pots of each treatment were cut for an analysis of the foliage. The plants had now flowered and were

Table I. *Analysis of soils, December* 6, 1934

Treatment gm. $(NH_4)_2SO_4$		Weight of moist soil	Reaction	Dry matter	Ammonia nitrogen mg./kg. dry soil	Nitrate nitrogen mg./kg. dry soil	Mineral nitrogen gm./pot	Extra mineral nitrogen gm./pot
Each dressing	Total added	kg.	*p*H	%				
0·0	0·0	1·28	7·1	76·5	7·6	50·7	0·06	—
0·25	1·75	1·45	6·3	66·7	14·6	394·0	0·39	0·33
0·50	3·50	1·16	6·0	74·9	71·8	378·0	0·39	0·33
1·00	7·00	1·56	5·2	68·8	272·0	626·0	0·96	0·91
					(Water-soluble) 144·0			

Table II. *Analysis of plants, December* 6, 1934

Treatment gm. $(NH_4)_2SO_4$		No. of plants found	Tops			Roots			Total nitrogen in plant gm./pot
			Weight dry	Nitrogen		Weight dry	Nitrogen		
Each dressing	Total added		gm./pot	%	gm./pot	gm./pot	%	gm./pot	
0·0	0·0	12	5·7	4·00	0·23	3·8	3·54	0·13	0·36
0·25	1·75	7	4·4	4·21	0·18	2·9	3·79	0·11	0·30
0·50	3·50	15	6·8	4·29	0·29	4·0	4·26	0·17	0·46
1·00	7·00	16	6·3	4·81	0·30	3·5	4·66	0·16	0·47

nearly mature. The nitrogen percentage on the dry matter varied between 3·11 and 3·47, but there was no significant difference between the treated and the controls (mean 3·24 ± 0·13). There was further no significant difference between the treated and the controls as regards the amount of foliage, expressed as fresh weight or as dry (mean dry wt. 45·9 gm. ± 3·6).

Immediately after cutting, growth of fresh shoots took place and the second crop was flowering when it was harvested on August 6. All the pots were harvested on this date, practically a year after the experiment had first been set up. Little difference was found in the nitrogen content of the tops of the plants in the various treatments, the main difference being that the tops of the plants which had not been cut down earlier were more fibrous, and consequently had a lower percentage nitrogen content than had the others of the same group. There were no significant differences between treatments in yield (mean dry wt. 39·6 gm. ± 2·5) or in nitrogen content (mean 2·44 per cent. ± 0·08). The details for nitrogen are given in Table III, in which the (*a*) and (*b*) series were those cut on May 29. It will be noted that the nitrogen content of all the plants is lower than it was in the earlier analyses.

Table III. *Nitrogen content of foliage, August* 6, 1935

Treatment gm. $(NH_4)_2SO_4$		Not cut on May 29	Cut on May 29	
			(*a*)	(*b*)
Each dressing	Total added	Nitrogen %	Nitrogen %	Nitrogen %
0·0	0·0	2·00	2·49	2·61
0·25	5·75	2·33	2·46	2·63
0·50	11·50	2·14	2·70	2·42
1·00	23·00	2·29	2·61	2·59

The treatments were continued after the foliage samples had been taken until August 29, when another cut was taken and the experiment was abandoned, the soils being analysed. Just before the final analyses were made the weather had been exceptionally wet, and, as a conse-

quence, some leaching had taken place from the pots. The final analyses are detailed in Table IV.

Table IV. *Analysis of soils, August* 29, 1935
(*average of three pots*)

Treatment gm. $(NH_4)_2SO_4$			Ammonia nitrogen mg./kg.	Nitrate nitrogen mg./kg.	Mineral nitrogen
Each dressing	Total added	Soil *p*H	dry soil	dry soil	gm./pot
0·0	0·0	6·9	8·2	5·6	0·015
0·25	6·0	6·3	8·9	9·2	0·020
0·5	12·0	5·8	30·2	8·5	0·043
1·00	24·0	4·6	105·0	8·4	0·125

The root systems were all very well developed and a few nodules were present on all the plants. There were no significant differences in yield of foliage (mean dry wt. 5·6 gm. ± 1·2). The nitrogen content of the plants is shown in Table V; the nitrogen content with the 1 gm. treatment was significantly above the others.

Table V. *Nitrogen content of foliage, August* 29, 1935
(*average of three pots*)

Treatment gm. $(NH_4)_2SO_4$		
Each dressing	Total added	Total nitrogen % of dry matter
0·0	0·0	3·73
0·25	6·0	3·68
0·50	12·0	3·73
1·00	24·0	4·50
	S.E.	±0·18

Experiment with sand cultures

A similar set of experiments was made with red clover grown in sand in glazed porcelain pots. This experiment was set up on May 21, 1935, when dressings of 0·0, 0·25, 0·50 and 1·00 gm. of ammonium sulphate were given to each set of pots. A basal dressing of Knop's solution (without nitrogen) was given to each pot on May 21, and again on June 18. The nitrogen treatments were continued on May 30, June 13, July 4, 18, August 1, 15, making in all seven applications of ammonium sulphate. This experiment also was stopped on August 29. The pots were kept in a glasshouse for the first six weeks and were then put out of doors. There was a spell of hot weather during July and the growth of all the plants was rather retarded but, in spite of this, on examination at the end of the experiment the roots were well developed, and a few large root nodules were present on all the plants. The plants receiving

the high sulphate dressings grew well, and while their leaves were on the whole narrower and darker green than those of the control plants, the amount of dry matter produced was about equal to that of the controls. The nitrogen content of the foliage was slightly greater in the plants with the high sulphate dressings, being on an average 2·93, 3·00, 3·36 and 3·32 per cent. of the dry matter in the 0, 0·25, 0·50 and 1 gm. sulphate pots respectively.

DISCUSSION AND CONCLUSIONS

A number of interesting points emerge from a consideration of the data obtained in this experiment. Some of these will be examined in more detail in later experiments. It does appear, however, as a general conclusion, that ammonium sulphate, as such, cannot be considered specifically toxic to Alsike or red clovers, even when applied in relatively enormous doses, *e.g.* 24 gm. in all per kg. of dry soil. In the early stages of growth the ammonium salt has a definitely stimulating effect on the plants, and at no stage does it have a retarding effect—the only difference in growth noticeable in the plant being the narrowing of the leaflets in the red clovers grown in sand with the highest sulphate treatments, and some reduction in the size of their roots.

These results harmonize with the conclusion reached by one of us (Richardson (2)) in an experiment with a number of nitrogenous treatments on mown grassland. He observed little direct injury to clovers from sulphate of ammonia, but found a significant negative correlation between the yield of herbage on all plots in the early part of the year and the growth of clover in July, and concluded that the chief factor in the repression of clover by sulphate of ammonia was simply competition with the extra growth of grass produced (see also Martin Jones (1)).

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REFERENCES

(1) JONES, MARTIN G. *Emp. J. exp. Agric.* (1933), **1**, 122–8 *et seq.*
(2) RICHARDSON, H. L. *J. agric. Sci.* (1934), **24**, 491–510.

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